FLUIDS AND THEIR EFFECT ON MEASUREMENTS OF LUNAR SOIL PARTICLE SIZE DISTRIBUTION.

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Introduction: From the late 1960s until now, lunar soil particle size distributions have typically been determined by sieving—sometimes dry, and at other times with fluids such as water or Freon [1-15]. Laser diffraction instruments allow rapid assessment of particle size distribution, and eventually may replace sieve measurements. However, when measuring lunar soils with laser diffraction instruments, care must be taken in choosing a carrier fluid that is compatible with lunar material.

Background: Distilled water is the fluid of choice for laser diffraction measurements of substances when there is no concern about adverse effects of water on the material being measured. When we began our analyses of lunar soils using laser diffraction, our first measurements were made with distilled water [14, 15]. Although the medians that we measured were comparable to earlier sieve data, the means tended to be significantly larger than expected.

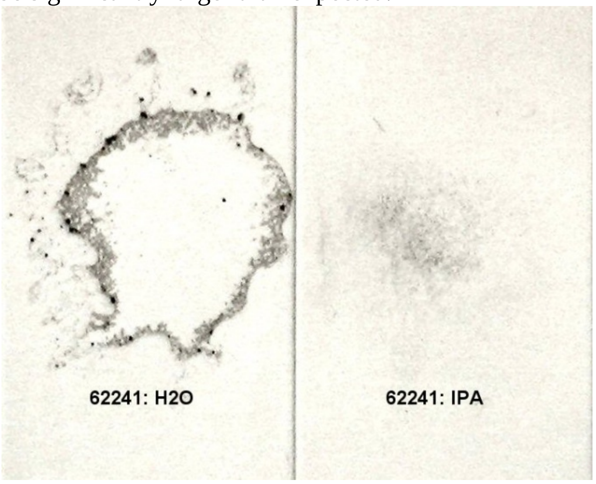

Figure 1. Dispersion tests with drops of water (left) and isopropanol (right) on a microscope slide, followed by application of a few mg of lunar soil 62241.

The effect of water vapor on lunar soil has been studied extensively [16-20]. The particles interact strongly with water vapor, and subsequent adsorptions of nitrogen showed that the specific surface area increased as much as threefold after exposure to moisture. It was observed that significant porosity had been generated by this exposure to water vapor. The possibility of other physical changes in the surfaces of the grains was not studied.

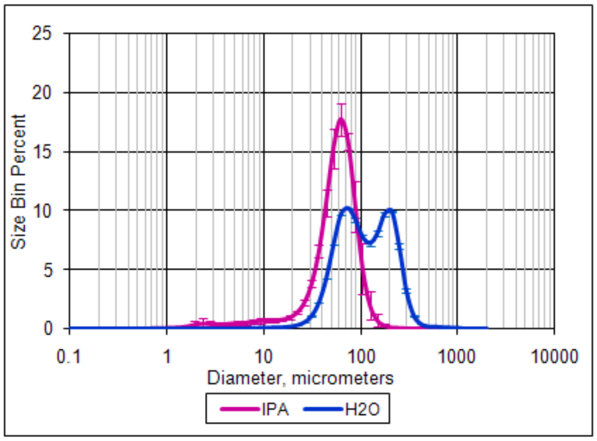

Figure 2. Measurements of a size-fractionated sample from Apollo 14 soil 14003,96 in water (blue) and in isopropanol (purple). Note the secondary peak at large (~200 μm) particle size in the histogram that was measured in water, thought to be caused by clumping.

Investigation: A dispersion test (as described in [21]) showed that the use of distilled water resulted in clumping of lunar soil (**Figure 1**). When a size-fractionated sample from lunar soil 14003,96 was measured in water, the volumetric mean was 121.1 μm, and the median was 98.04 μm (**Figure 2**). When another sample of the same material was measured with isopropanol, the volumetric mean was 59.63 μm, and the median was 57.30 μm. Variation in aliquots could not be invoked as the cause of this difference.

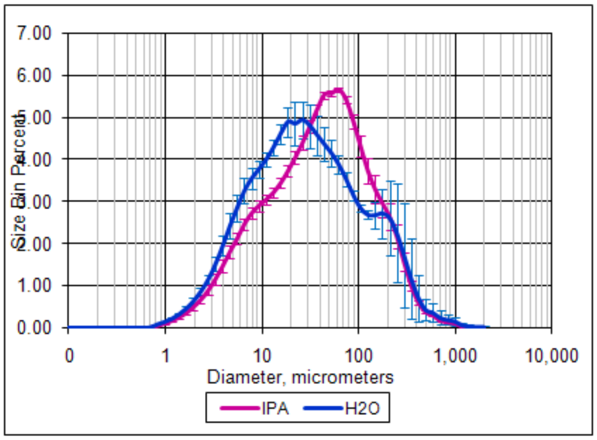

Figure 3. Measurements of Apollo 11 soil 10084 in water (blue) and isopropanol (purple).

A measurement of Apollo 11 soil 10084,2006 also showed significant variations related to the fluid that was used for measurement (Figure 3). Moreover, when comparing three separate measurements of the sample in water, the standard error was seen to be significantly larger than the standard error produced when isopropanol was used.

We found that the use of isopropyl alcohol resulted in little or no clumping. However, we were concerned that the isopropyl alcohol might partially dissolve and disaggregate the agglutinates because of their high proportion of potentially reactive glass, and thus create smaller particles than would have occurred naturally. To address this concern, we performed dissolution tests on lunar soil 14003,96 using isopropanol and water, and also using an acidic citrate-phosphate buffer (pH 4). The solutions were analyzed with ICP-MS. We observed that neutral pH water had a strong tendency to dissolve the silicon, calcium, and aluminum in lunar soil, and that the isopropanol dissolved a negligible amount of these elements when corrected for the blank control (Table 1).

Discussion and Conclusion: During our studies of lunar soils 10084, 14003, 62241and 61141, we found that water tends to cause clumping in the soil particles which cannot be de-agglomerated by sonication or by dispersant. Dissolution also occurs when lunar soil samples are placed in water. The finest fraction of lunar soil is known to concentrate both glass particles and plagioclase-rich particles. Our dissolution studies show that the major elements of plagioclase are the elements most affected by dissolution in water at neutral pH, but are not detectibly dissolved by isopropyl alcohol. Dissolution and clumping can apparently create a spurious bimodal distribution in water-exposed lunar soil. We therefore recommend the use of alternative fluids of lesser polarity for particle size measurements. Isopropyl alcohol appears to have negligible chemical effect on lunar soil grains and its use avoids spurious grain size artifacts.

Table 1. Dissolution of lunar soil 14003 in water, isopropanol, and in a pH 4 buffer solution. Controls were H_2O, isopropanol (IPA), and pH 4 Buffer soltuion without soil or other solute.

Element (mg/L)	H_2O	H_2O Control	Isopropanol (IPA)	IPA Control	pH 4 buffer Solution	pH 4 buffer Solution Control
Silicon (µg/L)	304.5	9	1280	1500	~35,000	~700
Calcium (mg/L)	0.53	0.14	0.1	0.2		
Aluminum (µg/L)	3	2	8	8	~22,500	~100
Magnesium (mg/L)	0.32	0.04	0.04	0.04		
Iron (µg/L)	5	8	20	20	~17,000	~100
Sulfur (mg/L)	0.7	0.7	1.6	1.6		
Titanium (µg/L)	1	1	4	4	~1700	~100

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